

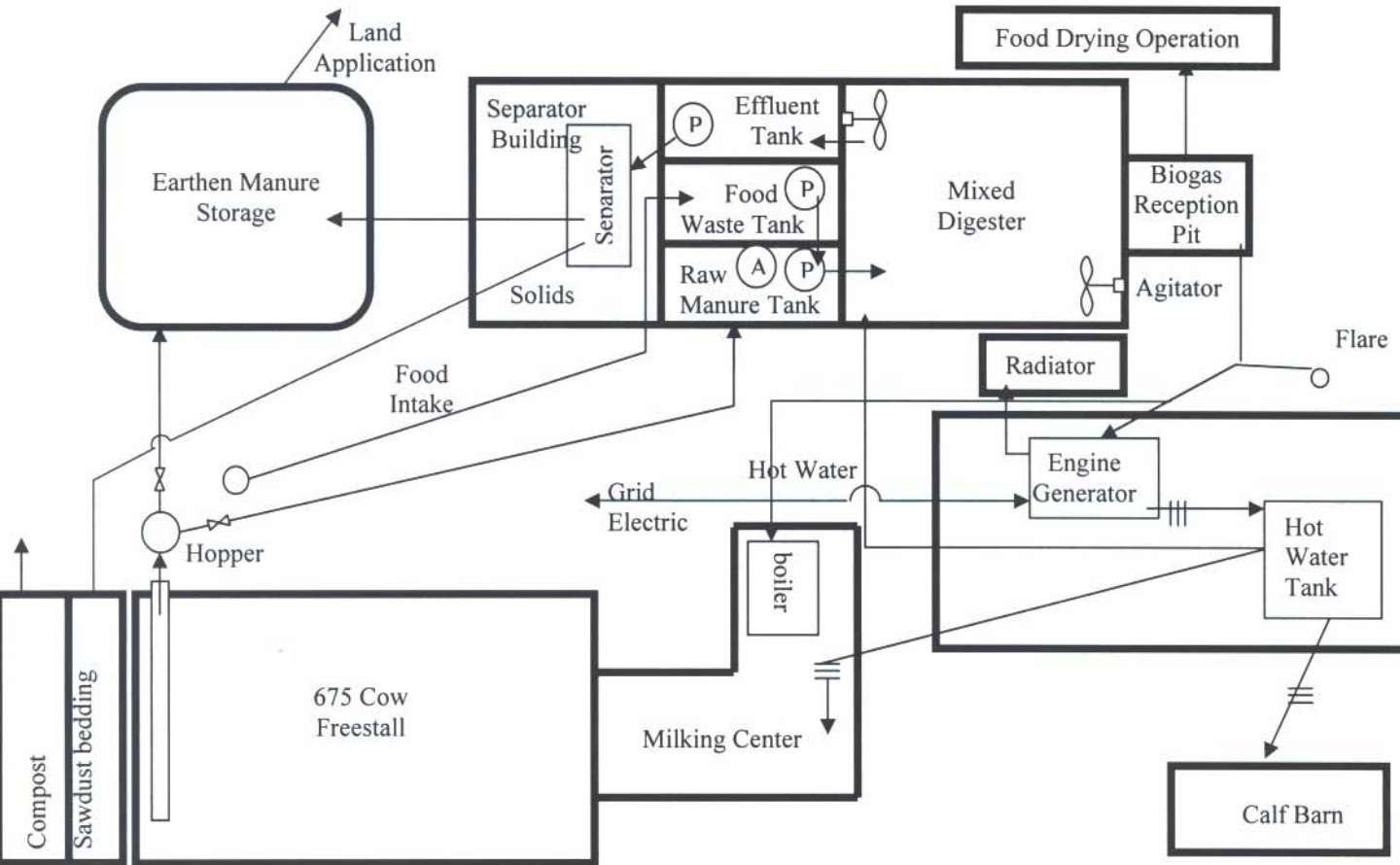


Conducting a hazard evaluation and developing a safety assessment protocol for farm anaerobic digesters, manure and biogas handling systems

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Flow diagram for digester, manure and biogas handling systems at Matlink (now Ridgeline) Dairy Farm



Results of combining Process Hazard Analysis and Job Hazard Analysis

...Some major issues

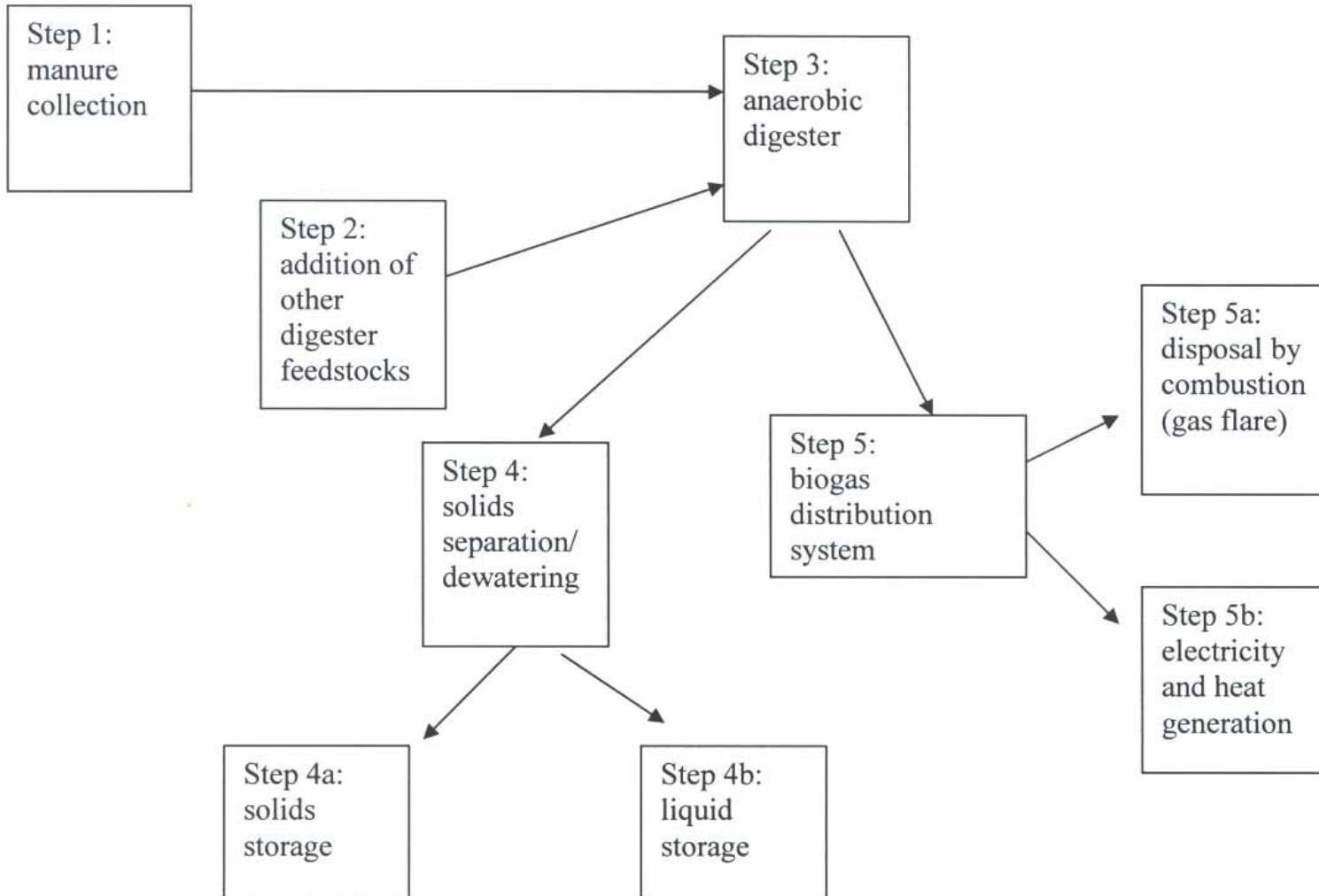
**...Detailed results obtained for
the anaerobic digester**



Hazard and Operability Analysis (HAZOP)

A process failure analysis technique which examines each step or unit operation to explore all of the possible ways that failures can occur.

Unit Operations



HAZARD AND OPERABILITY STUDY (HAZOP)

GUIDE WORDS	DEVIATION	POSSIBLE CAUSES	CONSEQUENCES	ACTION
NO or NOT				
MORE				
LESS				
AS WELL AS				
PART OF				
REVERSE				
OTHER THAN				

JOB HAZARD ANALYSIS



Consider:

- Regular procedures
- Off-specification procedures
- Unusual or infrequently done procedures

(Unfortunately, these will typically not be observable during a site visit.)

Conducting a job hazard analysis



Step	Hazard	Evaluation	Preventive Measure
1.			
2.			
3.			
4.			
5.			
Etc.			

Consider any and all types of hazards and combinations



- chemical: adverse health effects; reactivity, fire, explosion
- biological: disease, allergy, inflammation
- ergonomic: strains, sprains, over-exertions (acute or cumulative)
- occupational stress: including shiftwork and scheduling
- physical: radiation, thermal, EMF, vibration, noise
- trauma: slips, falls, impact, compression, cuts, amputation
- violence: verbal harassment, threats, physical assaults
- indoor air quality: non-industrial workplaces



Confined Space

An example of combined hazards

Asphyxiating atmosphere, including oxygen deficiency due to:

- displacement of air
- consumption of oxygen by welding, decay, or oxidation (corrosion)

Explosive atmosphere: gases or dusts

Toxic atmosphere

Mechanical hazard, needing lockout/tagout, line-breaking, or other procedures

Engulfment: drowning, buried alive

Manure generators



Figure 1

Alley scraper



Figure 2

Drive motor without guard



Figure 3

STEP 3: ANAEROBIC DIGESTION

OPERATIONS:

- Food waste pumped into raw manure tank.
- Manure and food waste mixed by agitator and pumped into digester.
- Digester is underground tank with a narrow divider only at the surface level forming two openings covered by impermeable rubberized-fabric covers which balloon upwards about 12-18 inches from the pressure of the biogas.
- Digester mixed by 2 propeller-type agitators.
- Digester effluent exits the digester into effluent tank, then is pumped to the adjacent separator building.
- If major problem occurs with any tanks, there is gravity spillway to storage lagoon.

STEP 3: ANAEROBIC DIGESTION

MAINTENANCE:

- Repair of pumps in manure tank and food waste tank.
- Repair of agitators in digester.
- Cleaning of digester tank, currently projected to be needed after 16 years of operation.
- Patching of cover; already performed once due to knife cut by vandalism.
- Remove foreign objects which entered the system from the barn.
- Historically, entry into the manure tank has taken place for:
 - removal of a board from a tank
 - cementing in place a tank's bottom drain plug which had been pushed out.

STEP 3: ANAEROBIC DIGESTION

HISTORY OF ACCIDENTS OR INCIDENTS OR SYMPTOMS:

None reported.

STEP 3: ANAEROBIC DIGESTION

IMPACT OF NEARBY OPERATIONS OR LAYOUT:

Not applicable

(see: reverse biogas flow from flare;
piping design lacks flame arrestor)

Flare



Figure 12

Biogas piping (notice scorching)

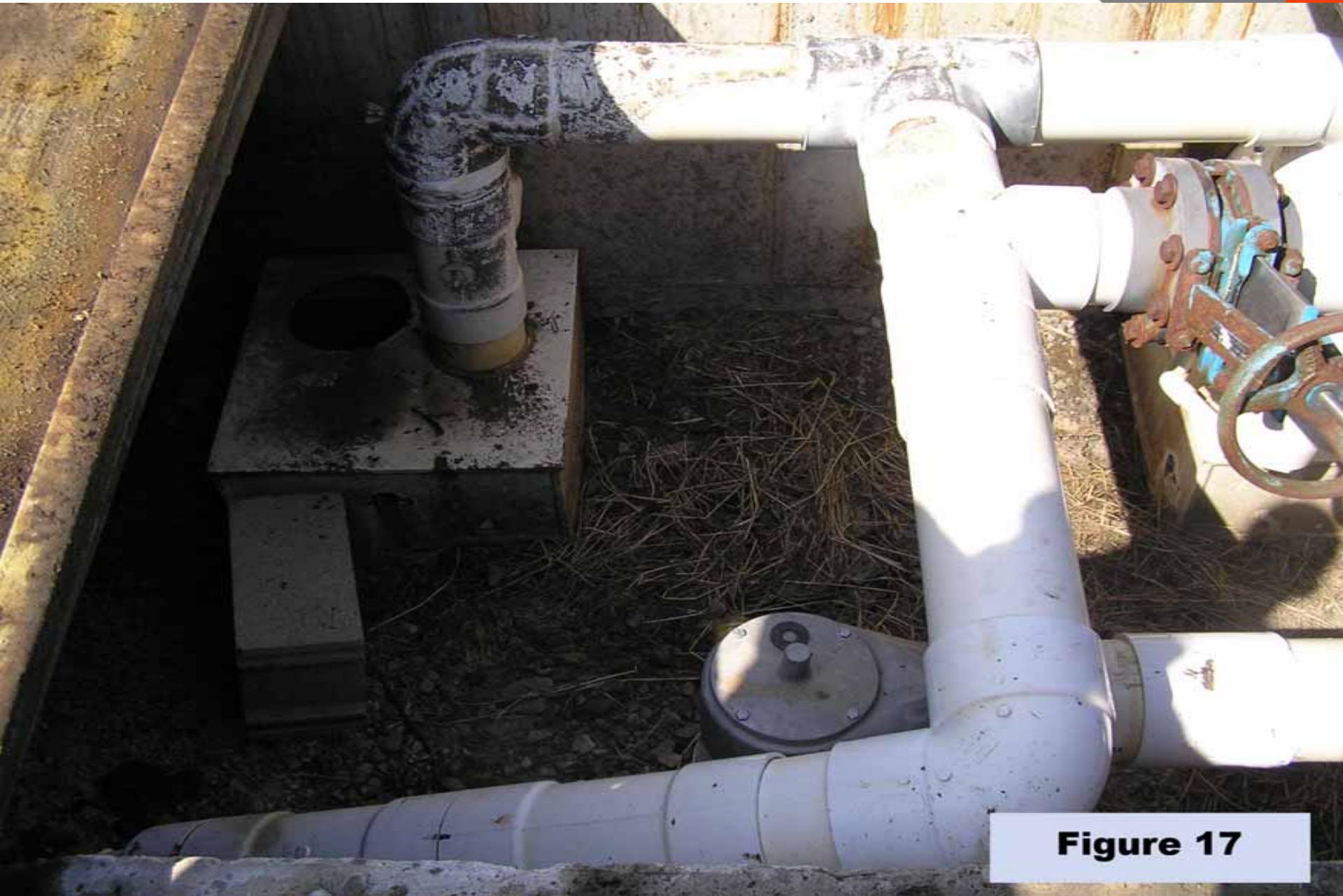


Figure 17

HAZARDS

The raw manure tank, food waste tank, effluent tank, agitator pits, and digester are confined spaces by definition as per 29 CFR 1910.146 (does not apply to agriculture) and would be expected to have hazards of:

- oxygen deficiency from methane and carbon dioxide
- hydrogen sulfide toxicity
- methane explosivity
- carbon dioxide toxicity
- engulfment (drowning)
- mechanical hazard from impact by agitator blades

EVALUATION

Biogas composition and hazards:

1. Methane

50-60%

- Asphyxiation can occur at 87% due to oxygen deficiency.
- Lower explosive limit (LEL) is 5%.**
- Upper explosive limit (UEL) is 15%.

2. Carbon dioxide

38-48%

- At concentrations of 11% or above, unconsciousness occurs in a minute. At 25-35%, convulsions occur. Immediately dangerous to life and health at 50,000 ppm or 5%.

3. Hydrogen sulfide

580 ppm

- Immediately dangerous to life and health at 300 ppm. At about 500 ppm, there can be pulmonary edema causing an imminent threat to life, and strong nervous system stimulation which can cause breathing to stop.
- LEL @ 4.3% or 43,000 ppm.
- UEL @ 46%

EVALUATION

- Historically, entry has been accomplished using a ladder, lifeline, full body harness, and supplied-air respirator or the use of a barn fan to provide ventilation.
- Current engineering controls in place include pumps and agitators attached by steel cables to winches, enabling withdrawal of these items to the surface for repair.
- Current signage indicates “respirator required” and “no smoking.”
- Fire extinguishers present.

PREVENTIVE MEASURES

- Repair to pumps and agitators does not require confined space entry. Due to the corrosive nature of hydrogen sulfide and moisture, to avoid having a cable break and a need for entry to arise, do regular cable inspection.
- Lockable hatch cover can prevent entry, but would probably be more cost-effective to use a fence with lockable gate which would encompass the tanks, digester, and gas reception pit; plus a fence around the base of the flare.

PREVENTIVE MEASURES

- Presence of confined spaces should be stated using warning signs at both ends of the digester, such as:

*TANKS, PITS, AND DIGESTER ARE
CONFINED SPACES*

These spaces may contain toxic or hazardous gases or lack sufficient oxygen to support life. Enter only after atmospheric monitoring indicates it is safe to do so.

Tank covers



HAZARDS: Wooden hatch covers are weakened. Some areas were reported as unable to support a person standing on top.

EVALUATION: Fall into tank with possible trauma. Engulfment (drowning) is a serious, potentially life-threatening risk.

PREVENTIVE MEASURES

Make new covers of a sturdier material to support weight of workers standing or walking across tops of tanks.

- If more than one person stands on the hatch cover at any one time (as occurred during my site visit), then the weight of multiple people would dictate the strength needed.
- If a pump is hoisted from a tank and allowed to rest on an adjacent hatch cover, perhaps alongside the operator of the winch, these weights should also be taken into account.

Digester



Figure 6

HAZARDS: Patching of leak in cover could involve inhalation of digester gas.

EVALUATION: Serious, potentially life-threatening.

PREVENTIVE MEASURES: Wear respirator. Remove ignition sources.

Dewatering of digester solids

Thermal burns from hot screw press.

Fall to lower level through hole in floor.



Figure 9

Dewatered solids storage



Figure 10

Biogas supplied to generator

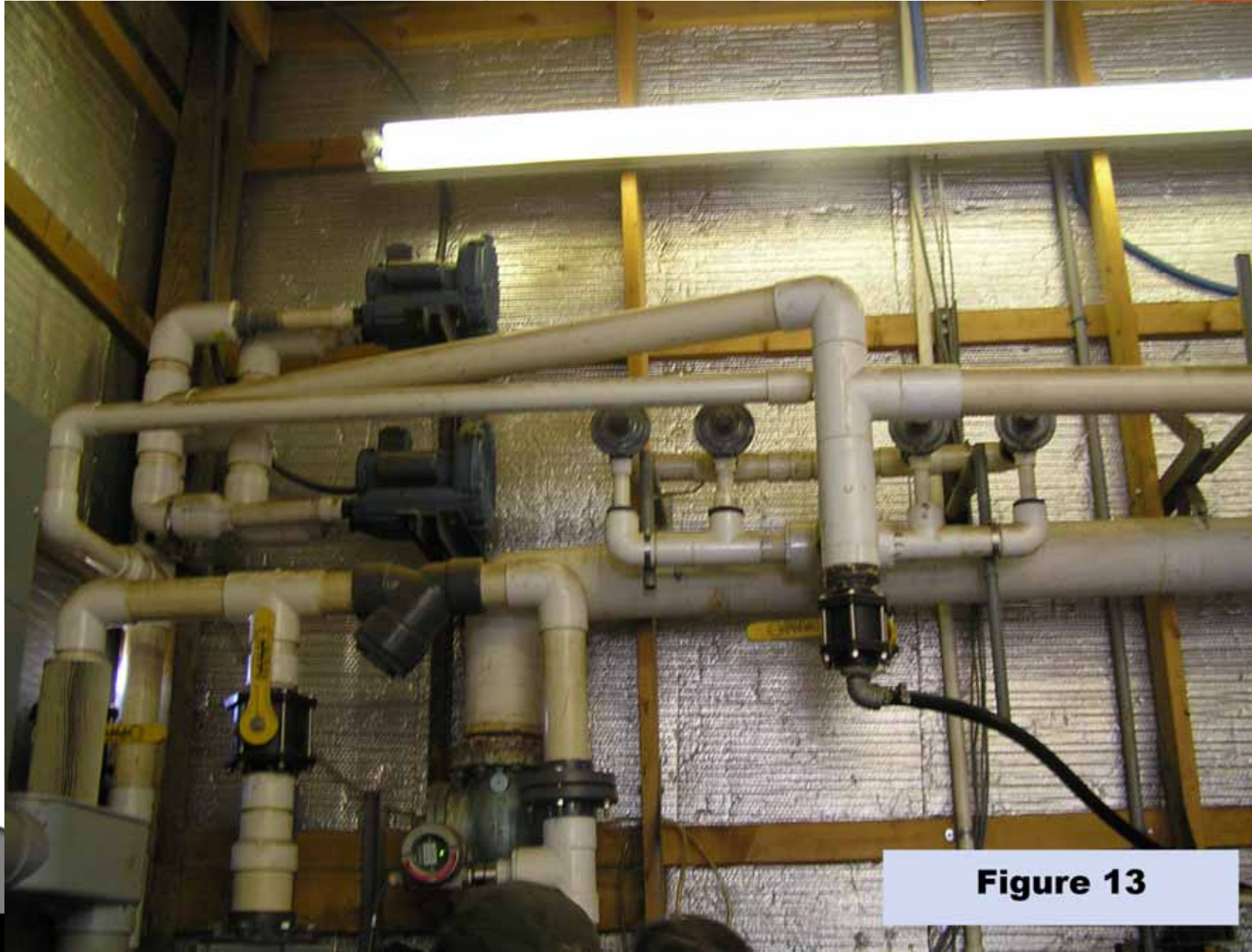


Figure 13

Generator

Noise; electrical hazards; oil on floor.



Figure 20

Exhaust from generator



Figure 14

Overall Hazards

- Heat stress – symptoms reported
- Cold stress – not perceived as a problem.
- Animal wastes and food wastes: bacteria, fungi, parasites, etc.

From the safety analysis at Matlink (now Ridgeline) Farm...

- ...derived a Generic Protocol for use by safety and health experts
- ...derived a Self-Assessment Protocol for use by farmers

Available at:

[http://www.manuremanagement.cornell.edu/
HTMLs/Safety.htm](http://www.manuremanagement.cornell.edu/HTMLs/Safety.htm)



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